

CLAIMS

1. A network system, comprising:

a first computer configured to maintain an object having an attribute, the attribute comprised of individual values, the individual values having conflict-resolution data;

a second computer configured to maintain a replica object, the replica object being replicated from the object; and

the second computer further configured to replicate the object from the first computer and resolve a replication conflict between a value of the attribute in the object and the value of the attribute in the replica object, the replication conflict being resolved with the conflict-resolution data.

2. A network system as recited in claim 1, wherein the second computer is further configured to compare the conflict-resolution data associated with the value of the attribute in the object and the conflict-resolution data associated with the value of the attribute in the replica object to resolve the replication conflict.

3. A network system as recited in claim 1, wherein the conflict-resolution data comprises a version indicator that corresponds to a version of an individual value.

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1 4. A network system as recited in claim 1, wherein the conflict-  
2 resolution data comprises a version number that corresponds to a version of an  
3 individual value, and wherein the second computer is further configured to:

4 compare the version number associated with the value of the attribute in the  
5 object and the version number associated with the value of the attribute in the  
6 replica object to resolve the replication conflict; and

7 update the value of the attribute in the replica object if the value has a lower  
8 version number than the value of the attribute in the object.

9  
10 5. A network system as recited in claim 1, wherein the conflict-  
11 resolution data comprises an update indicator that corresponds to when an  
12 individual value is updated.

13  
14 6. A network system as recited in claim 1, wherein the conflict-  
15 resolution data comprises an update timestamp that corresponds to when an  
16 individual value is updated, and wherein the second computer is further configured  
17 to:

18 compare the update timestamp associated with the value of the attribute in  
19 the object and the update timestamp associated with the value of the attribute in  
20 the replica object to resolve the replication conflict; and

21 update the value of the attribute in the replica object if the value has an  
22 earlier update timestamp than the value of the attribute in the object.

1 7. A network system as recited in claim 1, wherein the conflict-  
2 resolution data comprises a creation indicator that corresponds to when an  
3 individual value is created.

4  
5 8. A network system as recited in claim 1, wherein the conflict-  
6 resolution data comprises a creation timestamp that corresponds to when an  
7 individual value is created, and wherein the second computer is further configured  
8 to:

9 compare the creation timestamp associated with the value of the attribute in  
10 the object and the creation timestamp associated with the value of the attribute in  
11 the replica object to resolve the replication conflict; and

12 update the value of the attribute in the replica object if the value has an  
13 earlier creation timestamp than the value of the attribute in the object.

14  
15 9. A network system as recited in claim 1, wherein the conflict-  
16 resolution data comprises a version indicator that corresponds to a version of an  
17 individual value and an update indicator that corresponds to when the individual  
18 value is updated.

1     **10.** A network system as recited in claim 1, wherein the conflict-  
2 resolution data comprises a version number that corresponds to a version of an  
3 individual value and an update timestamp that corresponds to when the individual  
4 value is updated, and wherein the second computer is further configured to:

5         compare the conflict-resolution data associated with the value of the  
6 attribute in the object and the conflict-resolution data associated with the value of  
7 the attribute in the replica object; and

8         resolve the replication conflict in favor of the value that first has a higher  
9 version number, and second has a later update timestamp.

10  
11     **11.** A network system as recited in claim 1, wherein the conflict-  
12 resolution data comprises a version number that corresponds to a version of an  
13 individual value and an update timestamp that corresponds to when the individual  
14 value is updated, and wherein the second computer is further configured to:

15         compare the conflict-resolution data associated with the value of the  
16 attribute in the object and the conflict-resolution data associated with the value of  
17 the attribute in the replica object to resolve the replication conflict;

18         update the value of the attribute in the replica object if the value has a lower  
19 version number than the value of the attribute in the object; and

20         if the version number associated with the value of the attribute in the  
21 replica object is equivalent to the version number associated with the value of the  
22 attribute in the object, update the value of the attribute in the replica object if the  
23 value has an earlier update timestamp than the value of the attribute in the object.  
24  
25

1 **12.** A network system as recited in claim 1, wherein the conflict-  
2 resolution data comprises a creation indicator that corresponds to when an  
3 individual value is created, a version indicator that corresponds to a version of the  
4 individual value, and an update indicator that corresponds to when the individual  
5 value is updated.

6  
7 **13.** A network system as recited in claim 1, wherein the conflict-  
8 resolution data comprises a creation timestamp that corresponds to when an  
9 individual value is created, a version number that corresponds to a version of the  
10 individual value, and an update timestamp that corresponds to when the individual  
11 value is updated, and wherein the second computer is further configured to:

12 compare the conflict-resolution data associated with the value of the  
13 attribute in the object and the conflict-resolution data associated with the value of  
14 the attribute in the replica object; and

15 resolve the replication conflict in favor of the value that first has a later  
16 creation timestamp, second has a higher version number, and third has a later  
17 update timestamp.

14. A network system as recited in claim 1, wherein the conflict-resolution data comprises a creation timestamp that corresponds to when an individual value is created, a version number that corresponds to a version of the individual value, and an update timestamp that corresponds to when the individual value is updated, and wherein the second computer is further configured to:

compare the conflict-resolution data associated with the value of the attribute in the object and the conflict-resolution data associated with the value of the attribute in the replica object to resolve the replication conflict;

update the value of the attribute in the replica object if the value has an earlier creation timestamp than the value of the attribute in the object;

if the creation timestamp associated with the value of the attribute in the replica object is equivalent to the creation timestamp associated with the value of the attribute in the object, update the value of the attribute in the replica object if the value has a lower version number than the value of the attribute in the object; and

if the version number associated with the value of the attribute in the replica object is equivalent to the version number associated with the value of the attribute in the object, update the value of the attribute in the replica object if the value has an earlier update timestamp than the value of the attribute in the object.

15. A network system as recited in claim 1, wherein the individual values have an associated deletion indicator that is a null identifier to indicate the existence of a value of the attribute in the object.

16. A network system as recited in claim 1, wherein the individual values have an associated deletion indicator that corresponds to when an individual value is marked for deletion from the attribute in the object.

17. A network system as recited in claim 1, wherein the individual values have an associated deletion timestamp that corresponds to when an individual value is marked for deletion from the attribute in the object, and wherein the second computer is further configured to delete a value from the attribute in the object if the value has a deletion timestamp that indicates the value is marked for deletion.

18. A state-based replication system, comprising:  
an object having an attribute comprised of values, individual values having indicators to indicate a change to a value of the attribute;  
a computing device configured to replicate the object and, with the indicators, identify a change to a value of the attribute.

19. A state-based replication system as recited in claim 18, wherein the computing device is further configured to:  
maintain a replica object, the replica object being replicated from the object; and  
compare the object with the replica object to identify, with the indicators, a value replication conflict.

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1       **20.**     A state-based replication system as recited in claim 18, wherein the  
2 indicators comprise a version indicator that corresponds to a version of a value.

3  
4       **21.**     A state-based replication system as recited in claim 18, wherein the  
5 indicators comprise an update indicator that corresponds to when a value is  
6 changed.

7  
8       **22.**     A state-based replication system as recited in claim 18, wherein the  
9 indicators comprise a creation indicator that corresponds to when a value is  
10 created.

11  
12       **23.**     A state-based replication system as recited in claim 18, wherein the  
13 indicators comprise a version number that corresponds to a version of a value and  
14 an update timestamp that corresponds to when the value is changed.

15  
16       **24.**     A state-based replication system as recited in claim 18, wherein the  
17 indicators comprise a creation timestamp that corresponds to when a value is  
18 created, a version number that corresponds to a version of the value, and an update  
19 timestamp that corresponds to when the value is changed.

20  
21       **25.**     A state-based replication system as recited in claim 18, wherein the  
22 indicators comprise a deletion indicator that has a null identifier to indicate the  
23 existence of a value of the attribute.  
24  
25



1       **26.**     A state-based replication system as recited in claim 18, wherein the  
2 indicators comprise a deletion timestamp that corresponds to when a value is  
3 marked for deletion from the attribute.

4  
5       **27.**     A state-based replication system, comprising:  
6       a first computer configured to maintain a first data structure, the first data  
7 structure having a multi-valued attribute comprised of linked values, individual  
8 linked values having conflict-resolution information to indicate a change to a  
9 value of the attribute;

10       a second computer configured to maintain a second data structure having  
11 the multi-valued attribute comprised of the linked values; and

12       the first and second data structures configured to be replicated and to have a  
13 replication conflict between a value of the attribute in the first data structure and a  
14 value of the attribute in the second data structure resolved with the conflict-  
15 resolution information associated with the values.

16  
17       **28.**     A state-based replication system as recited in claim 27, wherein the  
18 first and second computers are further configured to:

19       compare the conflict-resolution information associated with the value of the  
20 attribute in the first data structure with the conflict-resolution information  
21 associated with the value of the attribute in the second data structure;

22       identify a replication conflict; and

23       resolve the replication conflict with the conflict-resolution information  
24 associated with the values.

1 **29.** A state-based replication system as recited in claim 27, wherein the  
2 conflict-resolution information comprises a version indicator that corresponds to a  
3 version of an individual linked value.  
4

5 **30.** A state-based replication system as recited in claim 27, wherein:  
6 the conflict-resolution information comprises a version number that  
7 corresponds to a version of an individual linked value;

8 the first and second computers are further configured to compare the  
9 version number associated with the linked value of the attribute in the first data  
10 structure with the version number associated with the linked value of the attribute  
11 in the second data structure;

12 the first computer is further configured to update the linked value of the  
13 attribute in the first data structure if the linked value has a lower version number  
14 than the linked value of the attribute in the second data structure; and

15 the second computer is further configured to update the linked value of the  
16 attribute in the second data structure if the linked value has a lower version  
17 number than the linked value of the attribute in the first data structure.  
18

19 **31.** A state-based replication system as recited in claim 27, wherein the  
20 conflict-resolution information comprises an update indicator that corresponds to  
21 when an individual linked value is changed.  
22  
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24  
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1     **32.**     A state-based replication system as recited in claim 27, wherein:  
2         the conflict-resolution information comprises an update timestamp that  
3     corresponds to when an individual linked value is changed;  
4         the first and second computers are further configured to compare the update  
5     timestamp associated with the linked value of the attribute in the first data  
6     structure with the update timestamp associated with the linked value of the  
7     attribute in the second data structure;  
8         the first computer is further configured to update the linked value of the  
9     attribute in the first data structure if the linked value has an earlier update  
10    timestamp than the linked value of the attribute in the second data structure; and  
11         the second computer is further configured to update the linked value of the  
12    attribute in the second data structure if the linked value has an earlier update  
13    timestamp than the linked value of the attribute in the first data structure.

14

15     **33.**     A state-based replication system as recited in claim 27, wherein the  
16    conflict-resolution information comprises a creation indicator that corresponds to  
17    when an individual linked value is created.

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1 **34.** A state-based replication system as recited in claim 27, wherein:  
2 the conflict-resolution information comprises a creation timestamp that  
3 corresponds to when an individual linked value is created;  
4 the first and second computers are further configured to compare the  
5 creation timestamp associated with the linked value of the attribute in the first data  
6 structure with the creation timestamp associated with the linked value of the  
7 attribute in the second data structure;  
8 the first computer is further configured to update the linked value of the  
9 attribute in the first data structure if the linked value has an earlier creation  
10 timestamp than the linked value of the attribute in the second data structure; and  
11 the second computer is further configured to update the linked value of the  
12 attribute in the second data structure if the linked value has an earlier creation  
13 timestamp than the linked value of the attribute in the first data structure.

14  
15 **35.** A state-based replication system as recited in claim 27, wherein the  
16 conflict-resolution information comprises a version indicator that corresponds to a  
17 version of an individual linked value and an update indicator that corresponds to  
18 when the individual linked value is changed.

19  
20 **36.** A state-based replication system as recited in claim 27, wherein the  
21 conflict-resolution information comprises a creation indicator that corresponds to  
22 when an individual linked value is created, a version indicator that corresponds to  
23 a version of the individual linked value, and an update indicator that corresponds  
24 to when the individual linked value is changed.  
25

1 37. A state-based replication system as recited in claim 27, wherein the  
2 individual linked values have an associated deletion indicator that is a null  
3 identifier to indicate the existence of a linked value of the multi-valued attribute.  
4

5 38. A state-based replication system as recited in claim 27, wherein the  
6 individual linked values have an associated deletion indicator that corresponds to  
7 when an individual linked value is marked for deletion from the multi-valued  
8 attribute.  
9

10 39. A computer-readable medium having stored thereon a data structure,  
11 comprising:

12 a first data field containing an attribute;

13 a second data field containing a value of the attribute contained in the first  
14 data field;

15 a third data field containing a version indicator corresponding to a version  
16 of the value contained in the second data field; and

17 a fourth data field containing an update indicator corresponding to when the  
18 version indicator contained in the third data field is changed.  
19

20 40. A computer-readable medium as recited in claim 39, wherein the  
21 data structure further comprises a fifth data field containing a creation indicator  
22 corresponding to when the value contained in the second data field is created.  
23  
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1        **41.**    A computer-readable medium as recited in claim 39, wherein the  
2 data structure further comprises a sixth data field containing a deletion indicator  
3 corresponding to the value contained in the second data field and configured to  
4 indicate when the value is marked for deletion from the data structure.

5  
6        **42.**    A network system, comprising:  
7            a first computer configured to replicate objects at an attribute level, and  
8 further configured to maintain an object having a multi-valued attribute, the multi-  
9 valued attribute comprised of individual values;

10           a second computer configured to replicate objects at an attribute value  
11 level, and further configured to maintain a second object, the second object having  
12 a multi-valued attribute comprised of individual values, the individual values  
13 configured to have conflict-resolution data;

14           the first computer further configured to:

15               replicate the second object from the second computer;

16               resolve a replication conflict between the object and the second  
17 object at the attribute level; and

18               resolve a replication conflict between the object and the second  
19 object at the attribute value level with the conflict-resolution data.

20  
21        **43.**    A network system as recited in claim 42, wherein the first computer  
22 first resolves the replication conflict between the object and the second object at  
23 the attribute level, and second resolves the replication conflict between the object  
24 and the second object at the attribute value level.  
25

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1       44.    A network system as recited in claim 42, wherein the first computer  
2 does not replicate a value from the second object if the value does not have  
3 conflict-resolution data.

4  
5       45.    A network system as recited in claim 42, wherein the first computer  
6 does not replicate a value from the second object if the value has null conflict-  
7 resolution data.

8  
9       46.    A network system as recited in claim 42, wherein the first computer  
10 resolves the replication conflict between the object and the second object at the  
11 attribute value level in favor of a value that has conflict-resolution data.

12  
13       47.    A network system as recited in claim 42, wherein the first computer  
14 resolves the replication conflict between the object and the second object at the  
15 attribute value level in favor of a value that has non-null conflict-resolution data.

16  
17       48.    A network system as recited in claim 42, wherein the second  
18 computer is further configured to:

- 19               replicate the object from the first computer;  
20               resolve a replication conflict between the object and the second  
21 object at the attribute level; and  
22               resolve a replication conflict between the object and the second  
23 object at the attribute value level with the conflict-resolution data.

1 49. A network system as recited in claim 48, wherein the second  
2 computer first resolves the replication conflict between the object and the second  
3 object at the attribute level, and second resolves the replication conflict between  
4 the object and the second object at the attribute value level.

5  
6 50. A network system as recited in claim 48, wherein the second  
7 computer does not replicate a value from the object if the value does not have  
8 conflict-resolution data.

9  
10 51. A network system as recited in claim 48, wherein the second  
11 computer does not replicate a value from the object if the value has null conflict-  
12 resolution data.

13  
14 52. A network system as recited in claim 48, wherein the second  
15 computer resolves the replication conflict between the object and the second  
16 object at the attribute value level in favor of a value that has conflict-resolution  
17 data.

18  
19 53. A network system as recited in claim 48, wherein the second  
20 computer resolves the replication conflict between the object and the second  
21 object at the attribute value level in favor of a value that has non-null conflict-  
22 resolution data.



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1        **54.**    A network system as recited in claim 48, wherein the second  
2 computer is further configured to delete a value from the second object if the value  
3 does not have conflict resolution data, and if the value is not replicated from the  
4 object.

5  
6        **55.**    A method, comprising:  
7        replicating an object stored in a first directory with a replica object stored in  
8 a second directory, the object and the replica object having an attribute comprised  
9 of individual values, the individual values having conflict-resolution data;  
10        comparing a value of the attribute in the object with a value of the attribute  
11 in the replica object to identify a replication conflict; and  
12        resolving the replication conflict with the conflict-resolution data.

13  
14        **56.**    A method as recited in claim 55, wherein the conflict-resolution data  
15 comprises a version number that corresponds to a version of an individual value,  
16 and wherein said comparing comprises determining if a value version number has  
17 been changed

18  
19        **57.**    A method as recited in claim 55, wherein the conflict-resolution data  
20 comprises a version number that corresponds to a version of an individual value,  
21 said comparing comprises determining if a value version number has been  
22 changed, and the method further comprises updating the value of the attribute that  
23 has a lower version number with the value of the attribute that has a higher version  
24 number.  
25

1 **58.** A method as recited in claim 55, wherein the conflict-resolution data  
2 comprises an update timestamp that corresponds to when an individual value is  
3 changed, and wherein said comparing comprises determining if a value update  
4 timestamp has been changed.

5  
6 **59.** A method as recited in claim 55, wherein the conflict-resolution data  
7 comprises an update timestamp that corresponds to when an individual value is  
8 changed, said comparing comprises determining if a value update timestamp has  
9 been changed, and the method further comprises updating the value of the attribute  
10 that has an earlier update timestamp with the value of the attribute that has a later  
11 update timestamp.

12  
13 **60.** A method as recited in claim 55, wherein the conflict-resolution data  
14 comprises a creation timestamp that corresponds to when an individual value is  
15 created, and wherein said comparing comprises determining if a creation  
16 timestamp has been changed.

17  
18 **61.** A method as recited in claim 55, wherein the conflict-resolution data  
19 comprises a creation timestamp that corresponds to when an individual value is  
20 created, said comparing comprises determining if a creation timestamp has been  
21 changed, and the method further comprises updating the value of the attribute that  
22 has an earlier creation timestamp with the value of the attribute that has a later  
23 creation timestamp.

1       **62.**     A method as recited in claim 55, wherein the conflict-resolution data  
2 comprises a version number that corresponds to a version of an individual value  
3 and an update timestamp that corresponds to when the individual value is changed,  
4 and wherein said comparing comprises determining if a value version number has  
5 been changed and if the value update timestamp has been changed.

6  
7       **63.**     A method as recited in claim 55, wherein the conflict-resolution data  
8 comprises a version number that corresponds to a version of an individual value  
9 and an update timestamp that corresponds to when the individual value is changed,  
10 and the method further comprises updating the value of the attribute that first has a  
11 lower version number, and second has an earlier update timestamp.

12  
13       **64.**     A computer-readable medium comprising computer executable  
14 instructions that, when executed, direct a computing system to perform the method  
15 of claim 63.

16  
17       **65.**     A method as recited in claim 55, wherein the conflict-resolution data  
18 comprises a creation timestamp that corresponds to when an individual value is  
19 created, a version number that corresponds to a version of the individual value,  
20 and an update timestamp that corresponds to when the individual value is changed,  
21 and wherein said comparing comprises determining if a value creation timestamp  
22 has been changed, if the value version number has been changed, and if the value  
23 update timestamp has been changed.

1 66. A method as recited in claim 55, wherein the conflict-resolution data  
2 comprises a creation timestamp that corresponds to when an individual value is  
3 created, a version number that corresponds to a version of the individual value,  
4 and an update timestamp that corresponds to when the individual value is changed,  
5 and the method further comprises updating the value of the attribute that first has  
6 an earlier creation timestamp, second has a lower version number, and third has an  
7 earlier update timestamp.

8  
9 67. A computer-readable medium comprising computer executable  
10 instructions that, when executed, direct a computing system to perform the method  
11 of claim 66.

12  
13 68. A method as recited in claim 55, wherein the individual values have  
14 a deletion timestamp that is a null identifier to indicate the existence of a value of  
15 the attribute.

16  
17 69. A method as recited in claim 55, wherein the individual values have  
18 a deletion timestamp that corresponds to when an individual value is marked for  
19 deletion from the attribute.

20  
21 70. A method as recited in claim 55, wherein the individual values have  
22 a deletion timestamp that corresponds to when an individual value is marked for  
23 deletion from the attribute, and the method further comprises deleting a value from  
24 the attribute if the value has a deletion timestamp that indicates the value is  
25 marked for deletion.

71. A computer-readable medium comprising computer executable instructions that, when executed, direct a computing system to perform the method of claim 70.

72. A computer-readable medium comprising computer executable instructions that, when executed, direct a computing system to perform the method of claim 55.

73. A method for replicating a linked value of a multi-valued attribute contained in an object, the linked value having conflict-resolution information and replicated from a replica object having the multi-valued attribute and the linked value, the method comprising:

comparing the conflict-resolution information associated with the linked value in the object with the conflict-resolution information associated with the linked value in the replica object;

identifying a replication conflict with the conflict-resolution information; and

resolving the replication conflict with the conflict-resolution information.

74. A method as recited in claim 73, wherein the conflict-resolution information comprises a version number that corresponds to a version of the linked value, and the method further comprising:

determining if the linked value version number has been changed; and

updating the linked value of the attribute that has a lower version number with the linked value of the attribute that has a higher version number.

1 75. A method as recited in claim 73, wherein the conflict-resolution  
2 information comprises an update timestamp that corresponds to when the linked  
3 value is changed, and the method further comprising:

4 determining if the linked value update timestamp has been changed; and  
5 updating the linked value of the attribute that has an earlier update  
6 timestamp with the linked value of the attribute that has a later update timestamp.

7  
8 76. A method as recited in claim 73, wherein the conflict-resolution  
9 information comprises a creation timestamp that corresponds to when the linked  
10 value is created, and the method further comprising:

11 determining if the linked value creation timestamp has been changed; and  
12 updating the linked value of the attribute that has an earlier creation  
13 timestamp with the linked value of the attribute that has a later creation timestamp.

14  
15 77. A method as recited in claim 73, wherein the conflict-resolution  
16 information comprises a creation timestamp that corresponds to when the linked  
17 value is created, a version number that corresponds to a version of the linked  
18 value, and an update timestamp that corresponds to when the linked value is  
19 changed.

1       **78.**    A method as recited in claim 73, wherein the conflict-resolution  
2 information comprises a creation timestamp that corresponds to when the linked  
3 value is created, a version number that corresponds to a version of the linked  
4 value, and an update timestamp that corresponds to when the linked value is  
5 changed, and the method further comprises updating the linked value of the  
6 attribute if the linked value first has an earlier creation timestamp, second has a  
7 lower version number, and third has an earlier update timestamp.

8  
9       **79.**    A computer-readable medium comprising computer executable  
10 instructions that, when executed, direct a computing system to perform the method  
11 of claim 78.

12  
13       **80.**    A computer-readable medium comprising computer executable  
14 instructions that, when executed, direct a computing system to perform the method  
15 of claim 73.

16  
17       **81.**    A method, comprising:  
18       replicating a first object with a second object, the first object having an  
19 attribute comprised of individual values, the second object having an attribute  
20 comprised of individual values configured to have associated conflict-resolution  
21 data;

22       resolving first a replication conflict between the first object and the second  
23 object at an attribute level; and

24       resolving second, with the conflict-resolution data, a replication conflict  
25 between the first object and the second object at an attribute value level.

1  
2 **82.** A method as recited in claim 81, further comprising determining  
3 whether a value corresponding to the second object has conflict-resolution data  
4 and said replicating the value if said determining that the value has conflict-  
5 resolution data.

6  
7 **83.** A method as recited in claim 81, further comprising determining  
8 whether a value corresponding to the second object has non-null conflict-  
9 resolution data and said replicating the value if said determining that the value has  
10 non-null conflict-resolution data.

11  
12 **84.** A method as recited in claim 81, said resolving the replication  
13 conflict between the first object and the second object at the attribute value level in  
14 favor of a value that has conflict-resolution data.

15  
16 **85.** A method as recited in claim 81, further comprising deleting a value  
17 corresponding to the second object if the value does not have conflict-resolution  
18 data and if the value is not replicated.

19  
20 **86.** A computer-readable medium comprising computer executable  
21 instructions that, when executed, direct a computing system to perform the method  
22 of claim 81.  
23  
24  
25